Changes to Cloud Microphysics and Aerosol Properties in an Urban Plume

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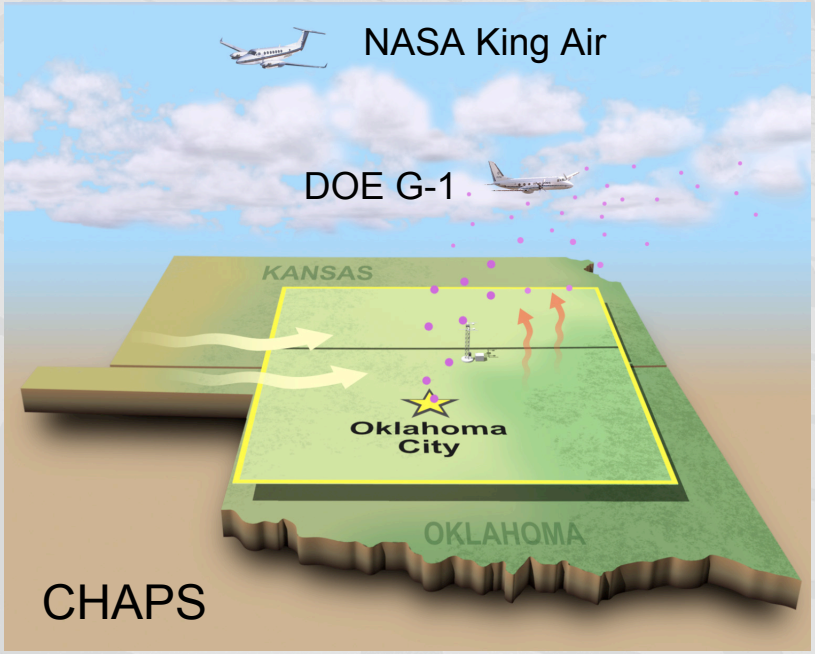

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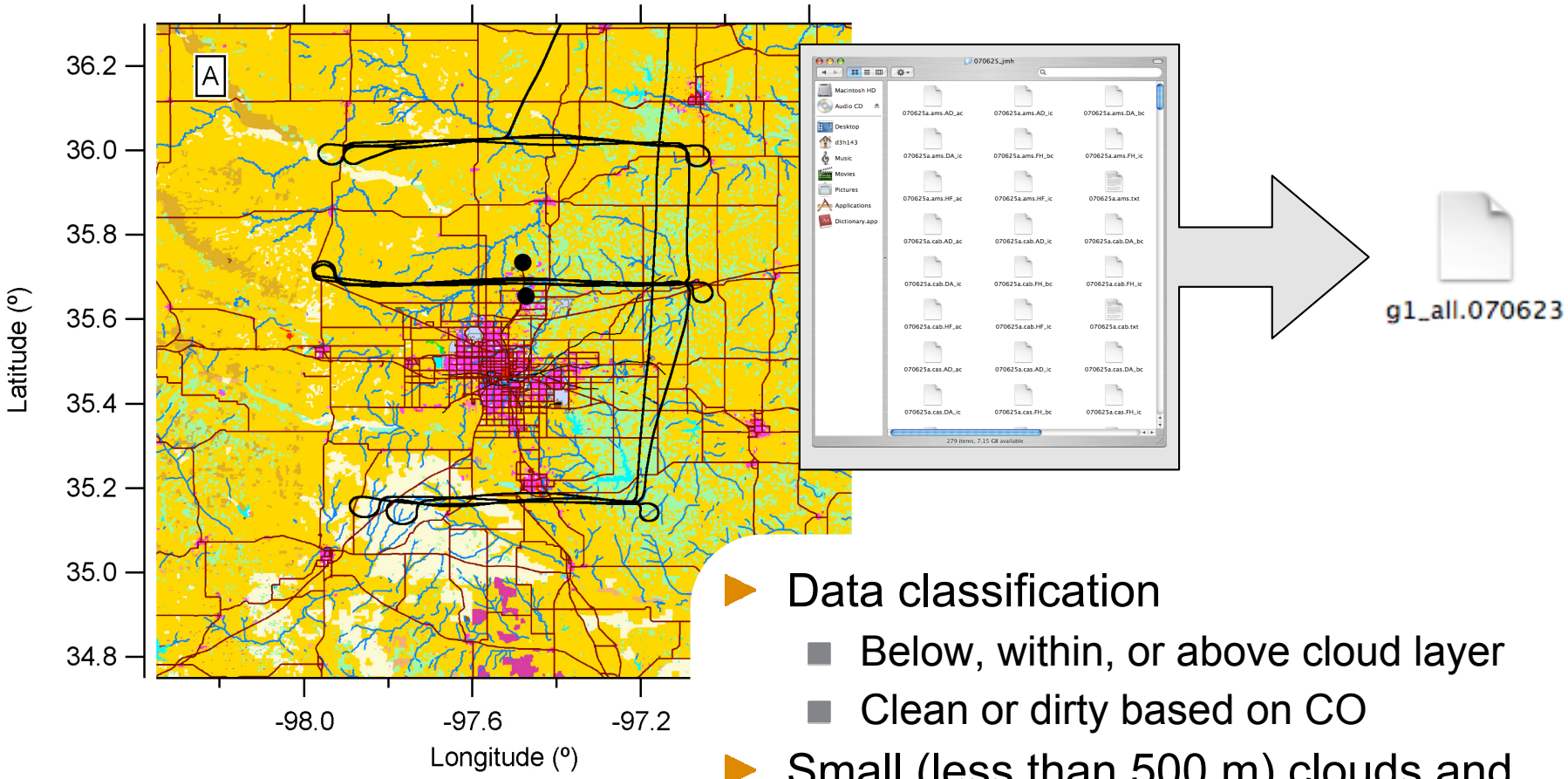
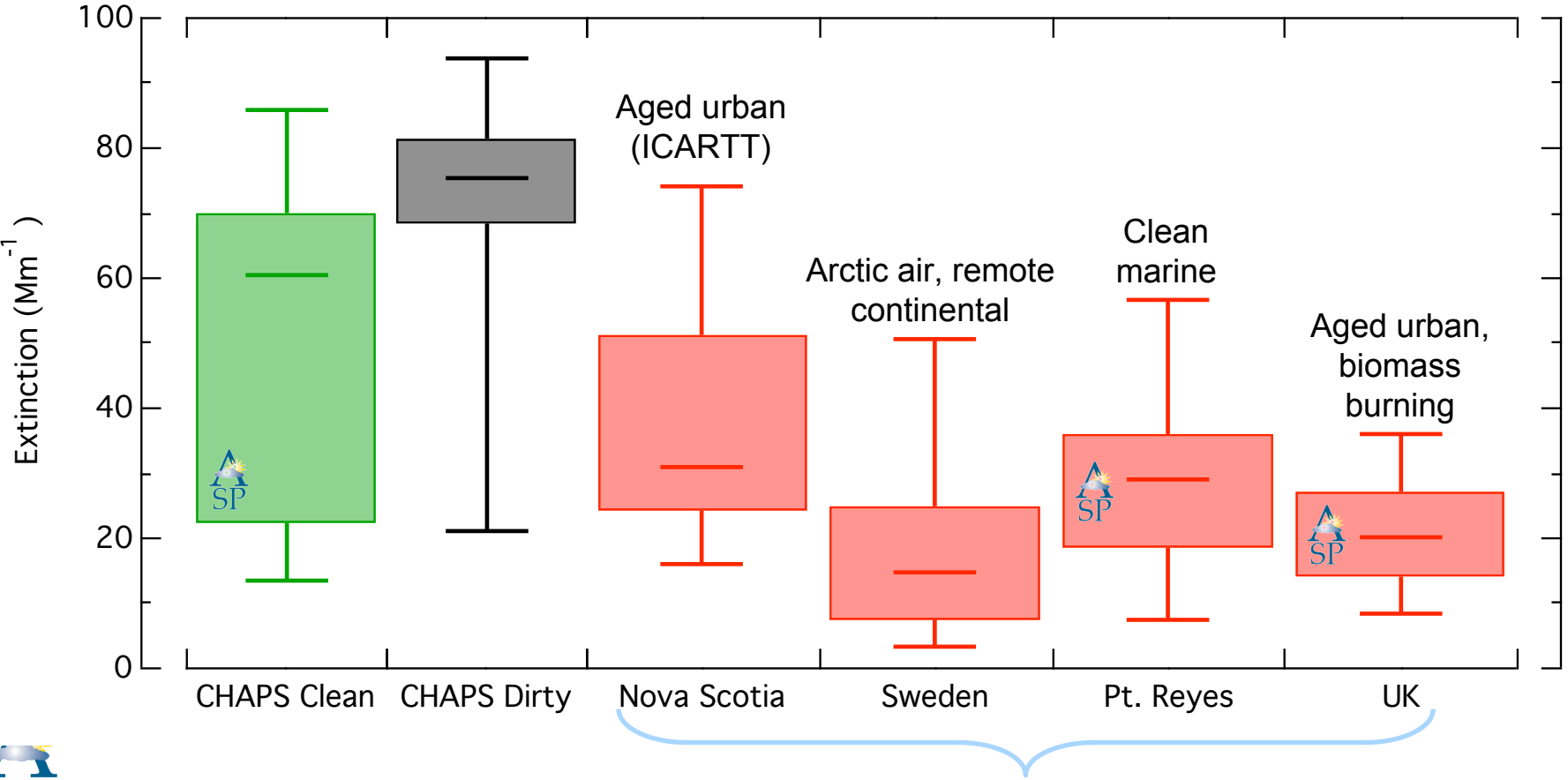
Amalgamated Data



- Data classification
  - Below, within, or above cloud layer
  - Clean or dirty based on CO
- Small (less than 500 m) clouds and small gaps (less than 500 m) between clouds were excluded from the analysis

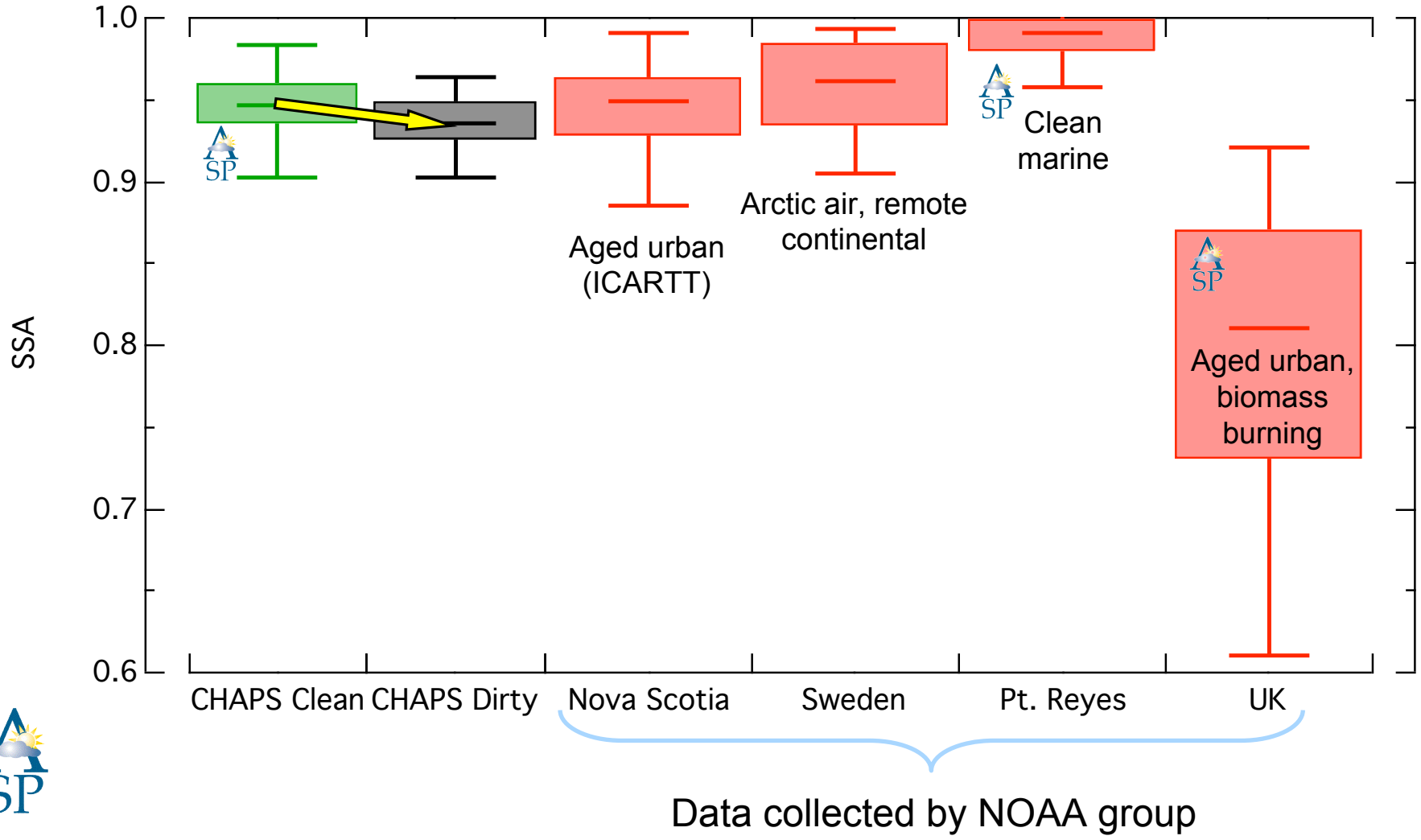
Sub-Cloud Optical Properties: Extinction

- Increased extinction associated with OKC plume



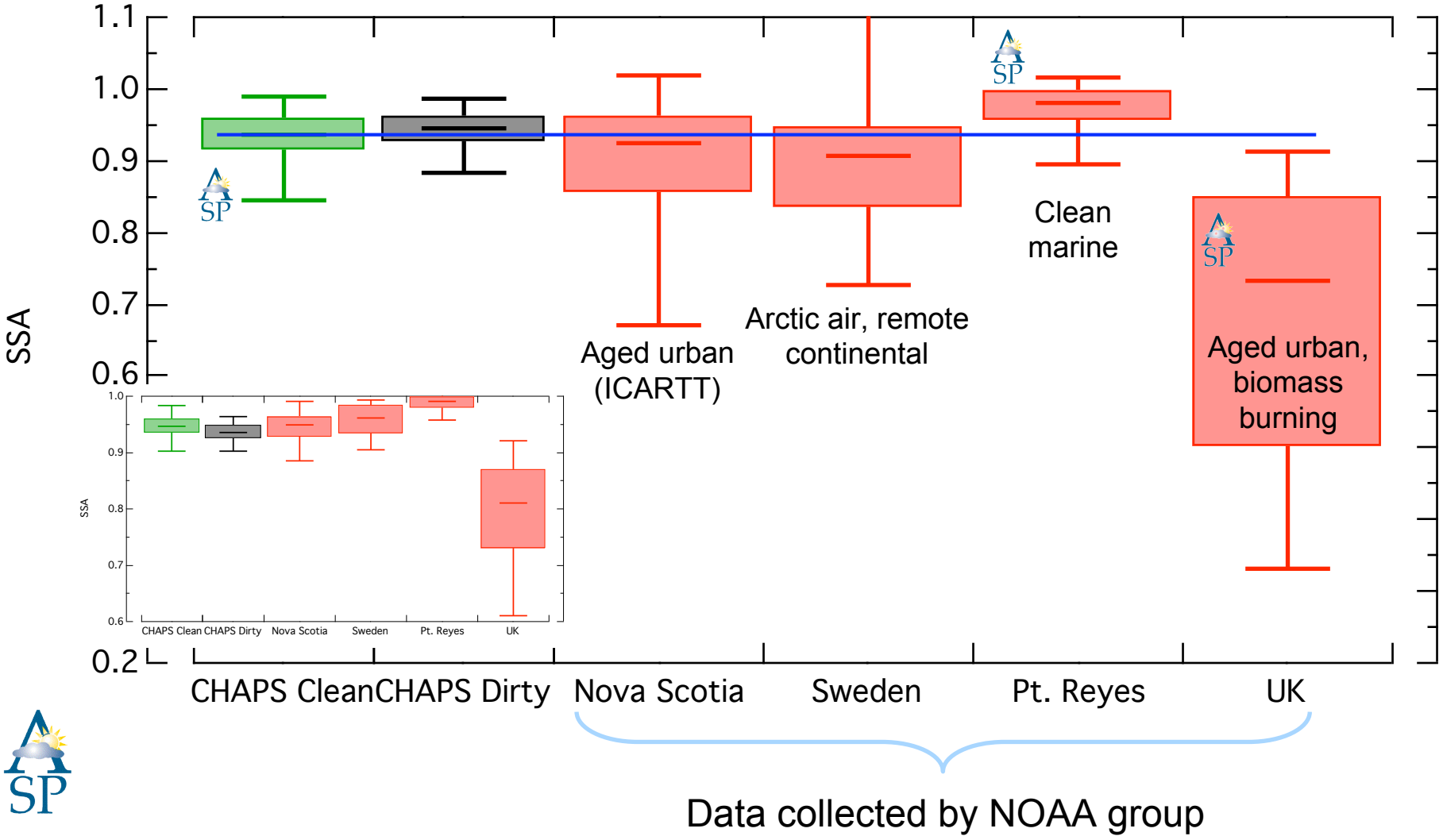
Sub-Cloud Optical Properties: SSA

- Decrease in SSA associated with OKC plume



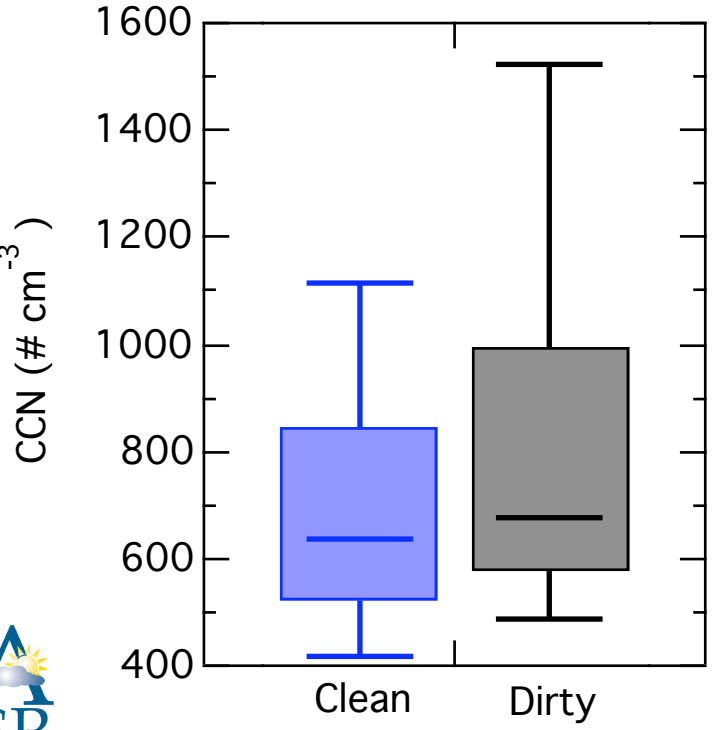
Interstitial Cloud Aerosol Properties: SSA

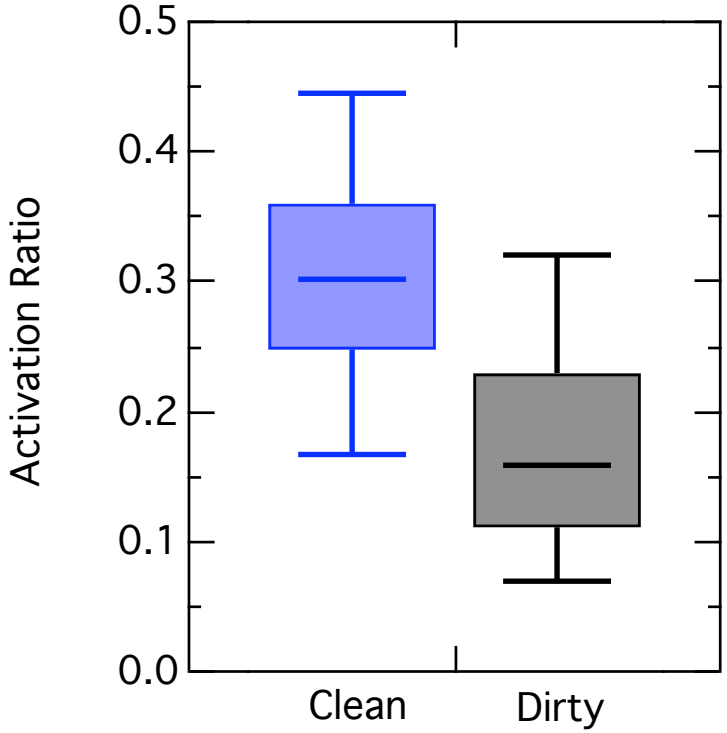
- CHAPS data has high SSA relative to other sites



Sub-Cloud CCN

- CCN computed for 0.3% supersaturation
  - Slightly more CCN in dirty air





- Activation ratio (CCN/CN)
  - Smaller in dirty air
  - Changes in size distribution or chemical composition?

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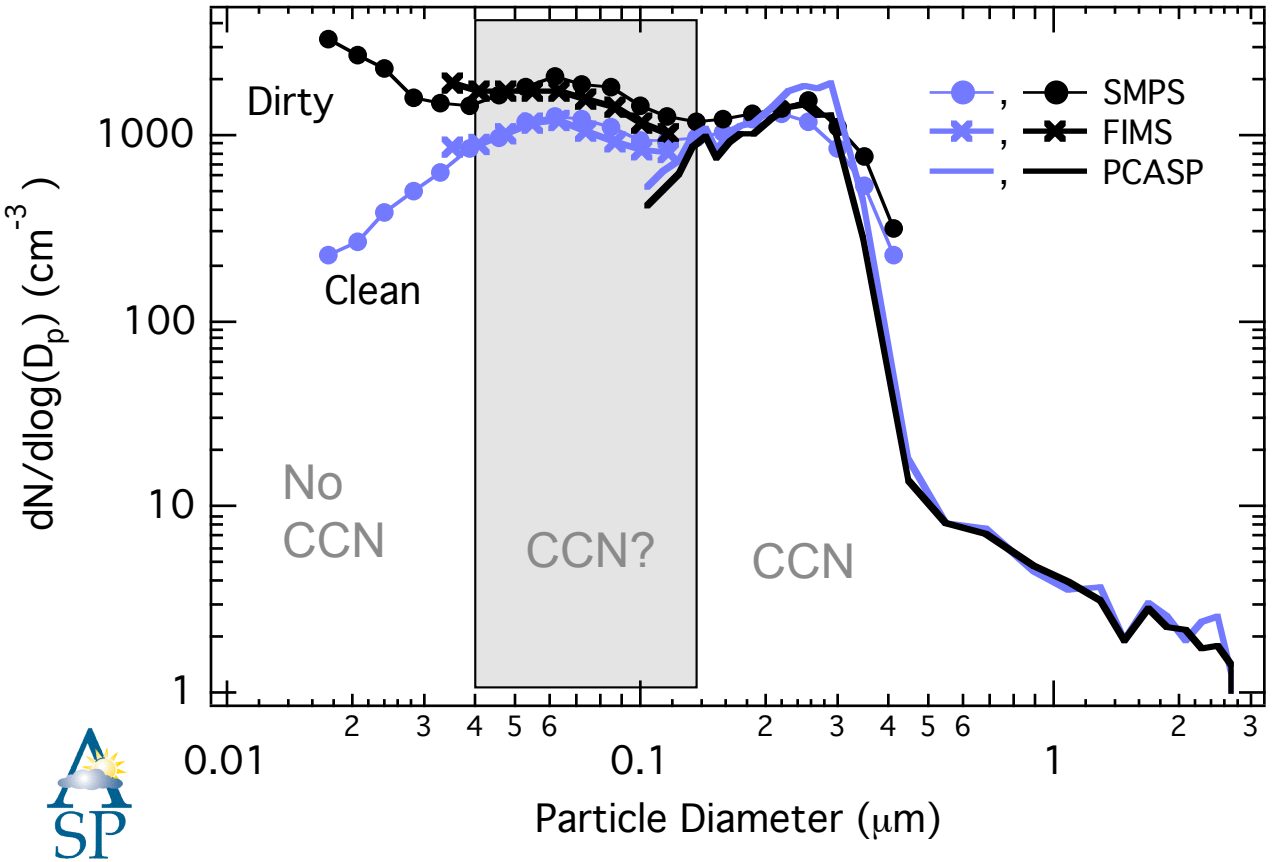
Sub-Cloud CCN: Cont.

- Sample case, dirty air—more particles D_p < 0.04 μm
  - Particles smaller than 0.04 μm generally do not act as CCN



- Particle size distribution can explain (at least some) of the change in CCN/CN ratio
- But…

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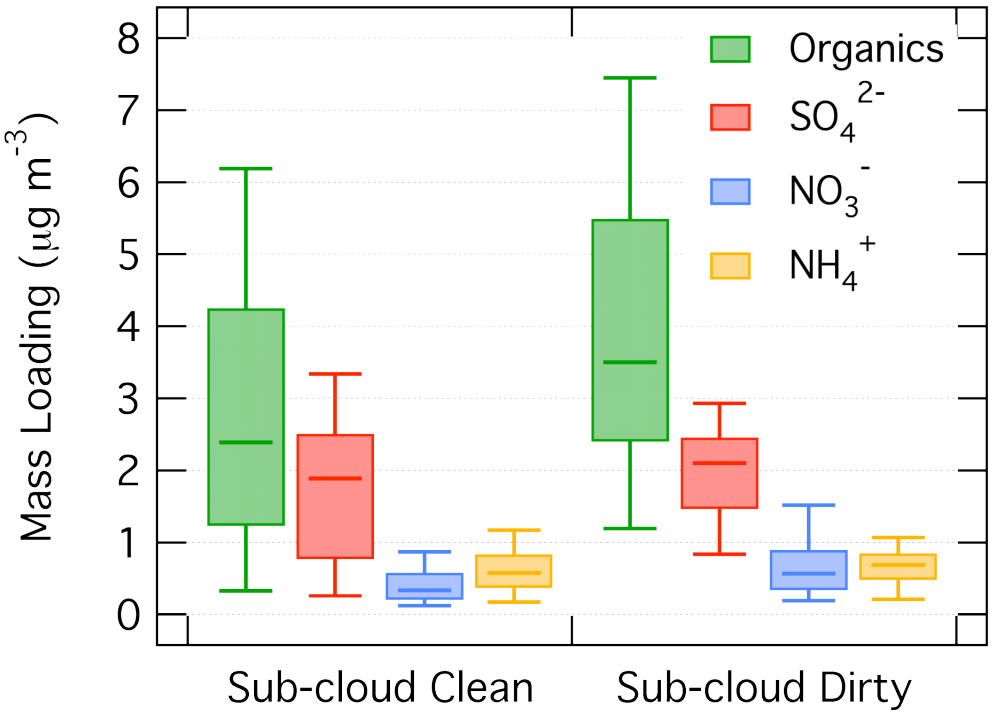
Chemical Composition: Below-cloud

- Particles are generally organics and sulfates
- OKC plume can be identified from AMS data
  - Increase in particle mass loading
  - Relative increase in organics
- But what happens as aerosols are lofted into the clouds?



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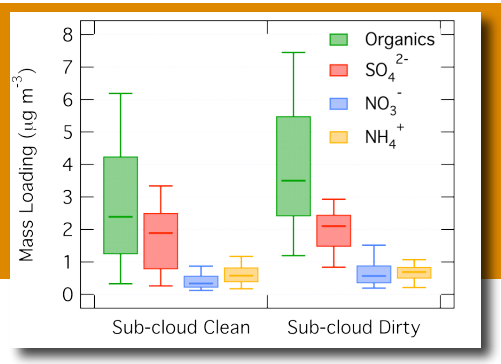
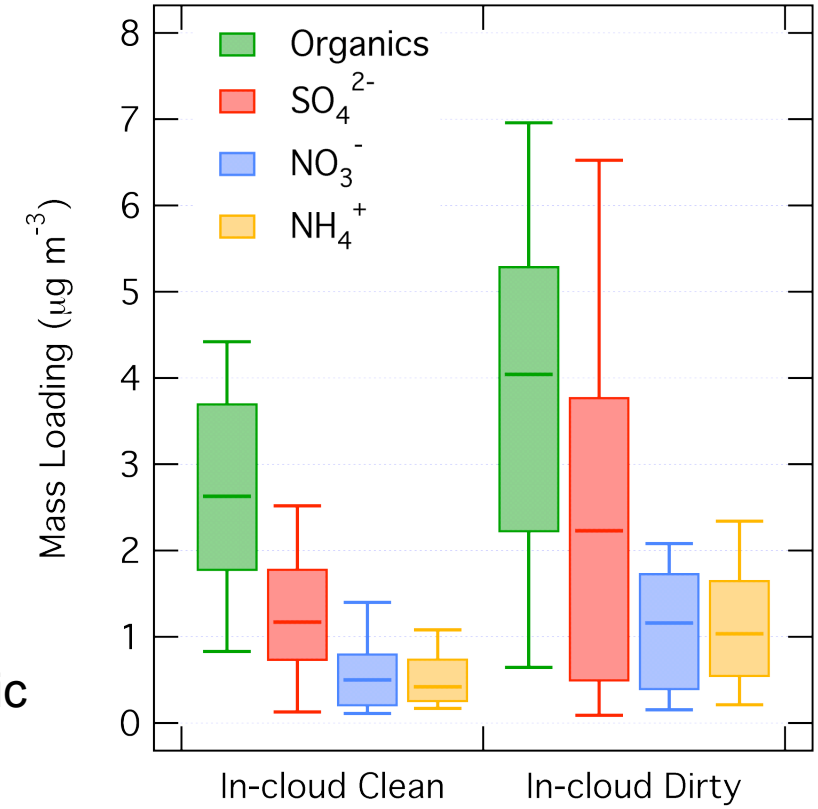
Chemical Composition: In-cloud



- Cloud droplets are dried, and residual kernel is sampled by AMS.
  - CVI enriches particle mass

In dirty clouds…

- Relative increase in sulfate
  - Org. larger by 1.5, SO_4 larger by nearly 2.
- Increased nitrate
  - Cloud droplet residuals from dirty clouds are nearly neutralized
    - Dirty $[NH_4^+]/[SO_4^{2-}] \sim 2$
  - Clean cloud residuals are more acidic
    - Clean $[NH_4^+]/[SO_4^{2-}] \sim 1.7$



Systematic changes to particle populations

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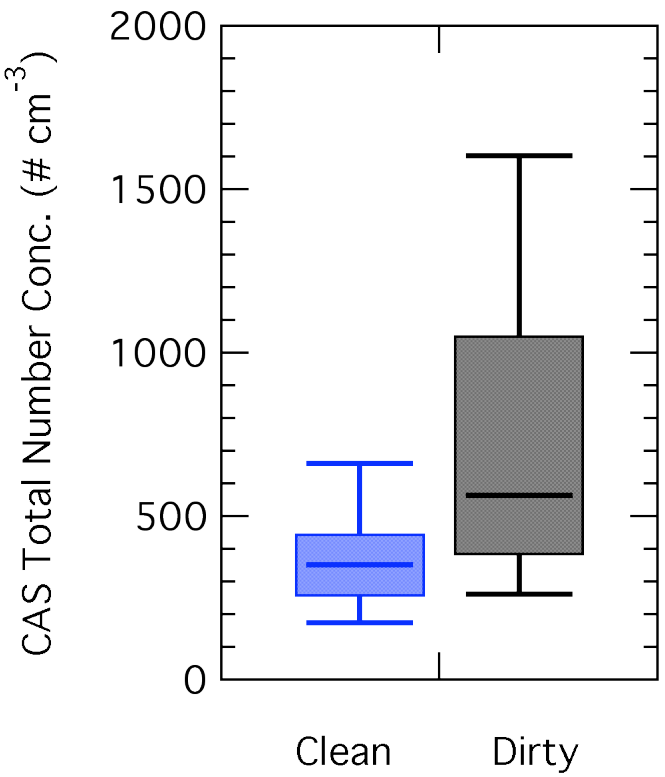
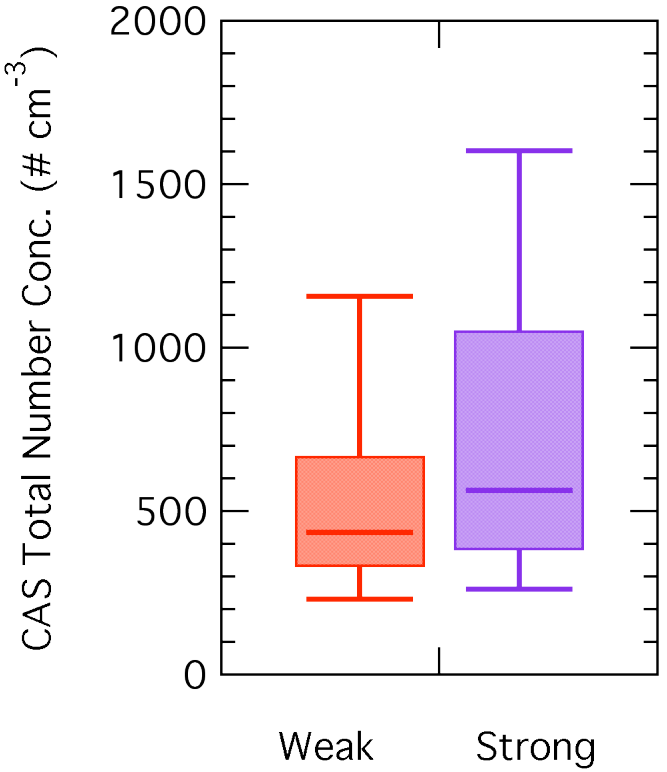
What Happens to the Clouds?

- Total number of droplets increases in dirty clouds
- But, what about the updraft strength?





ARM Atmospheric Radiation Measurement

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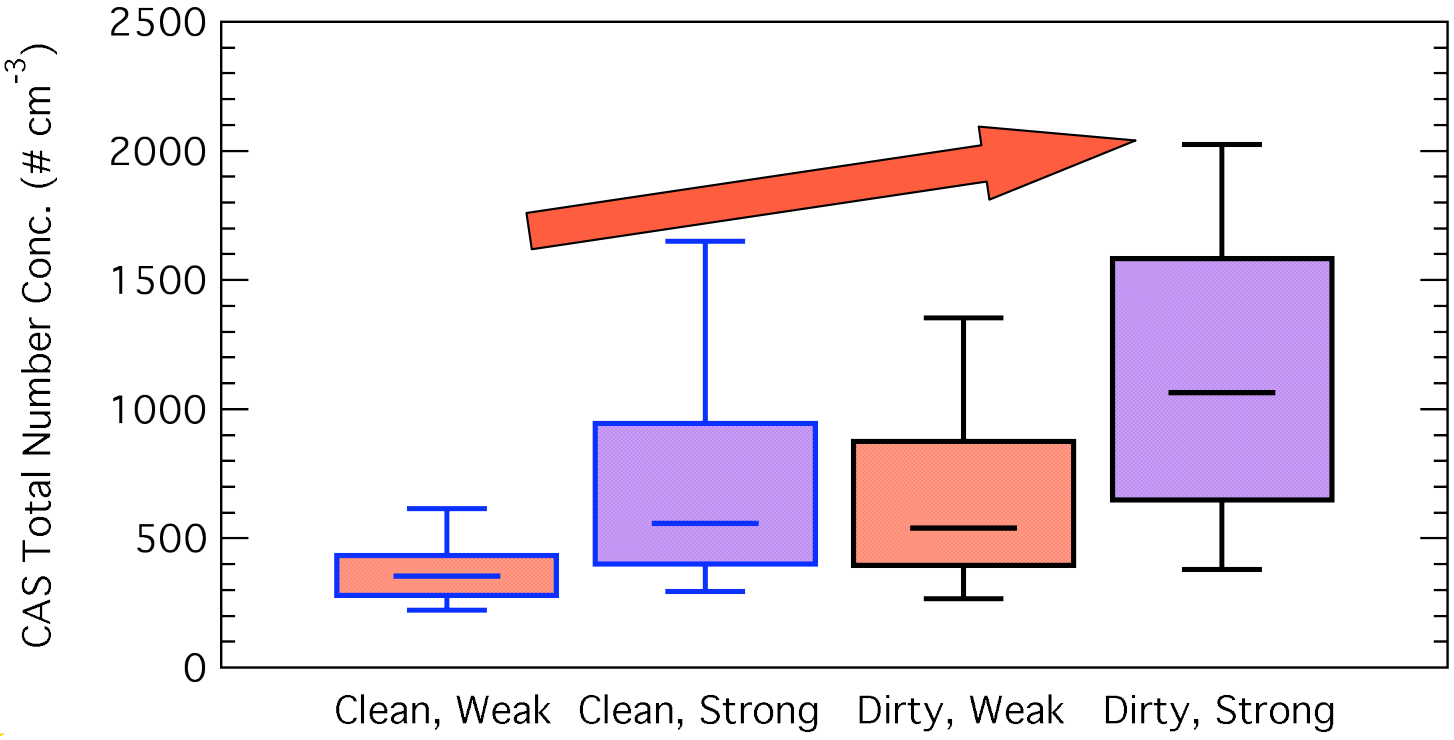
Cloud Microphysics: Four Classes

- Cloud-droplet number concentration is related to both aerosol loading and updraft strength
  - Break into four classes



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Conclusions & Future Work
Did we see what we expected to see?

- A moderately sized city changes aerosol optical, physical, and chemical properties
  - Increase in extinction, and decrease in SSA associated with OKC
  - Changes in the mass of organics, sulfate, and nitrate
- Chemical composition of cloud droplet kernels varies between clean and dirty air
  - Changes in $[NH_4^+]/[SO_4^{2-}]$
  - Possible changes in sulfate and organics associated with POA and SOA
- Cloud microphysics
  - Some evidence for aerosol indirect effect, but cloud updraft strength is also important
- Future work
  - Detailed analysis of CCN data and VOCs
  - Do these changes in chemical properties lead to changes in the particle optical properties?
  - Modeling efforts with LES and regional scale models

BAMS paper has been submitted!

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Acknowledgments

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- Staff in the field
  - Rich Coulter, Pete Daum, Yury Desyaterik, Manvendra Dubey, Chuck Greenwood, Bob Hannigan, Dick Hone, Jason Olfert, Larry Kleinman, Connor Flynn, Pete Lamb, Chuck Long, Tim Martin, Claudio Mazzoleni, Mark Miller, Matt Newburn, Mikhail Pekour, Debbie Ronfeld, Beat Schmid, Patrick Sheridan

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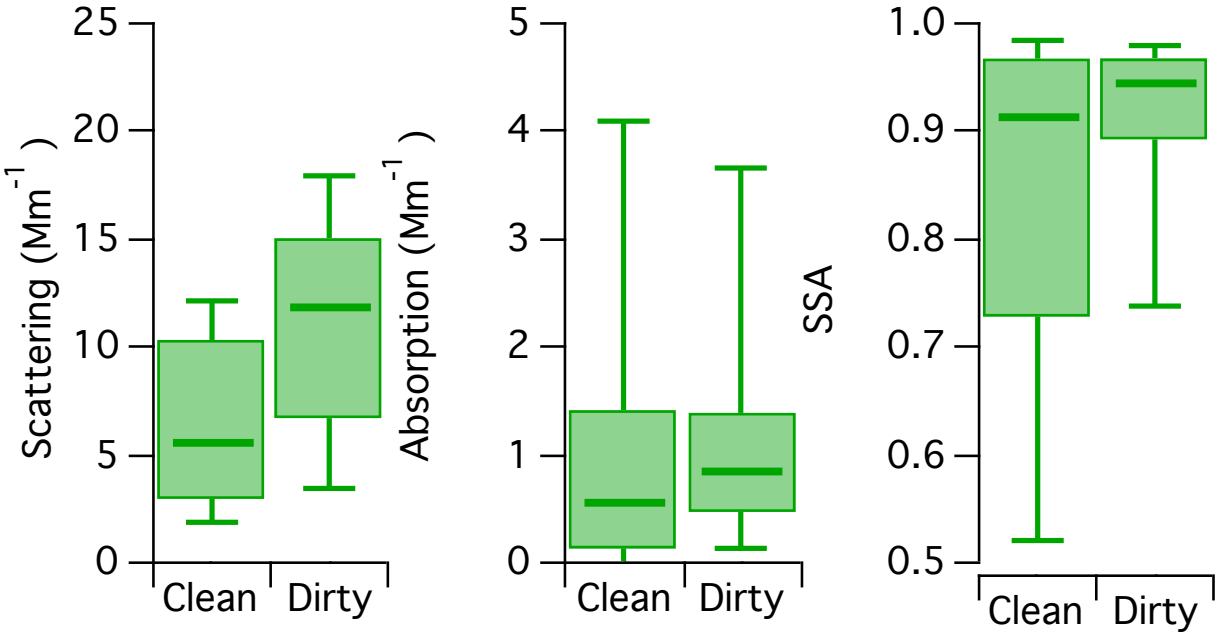
Supporting Information

Cloud-Processing Within Clouds

- Increase in scattering and absorption from dried droplet kernels associated with OKC plume
  - Large decrease in scattering in both cases compared to subcloud case
  - Large amount of noise associated with absorption measured in clouds
- Increase in SSA (compared to increase in sub-cloud layer)



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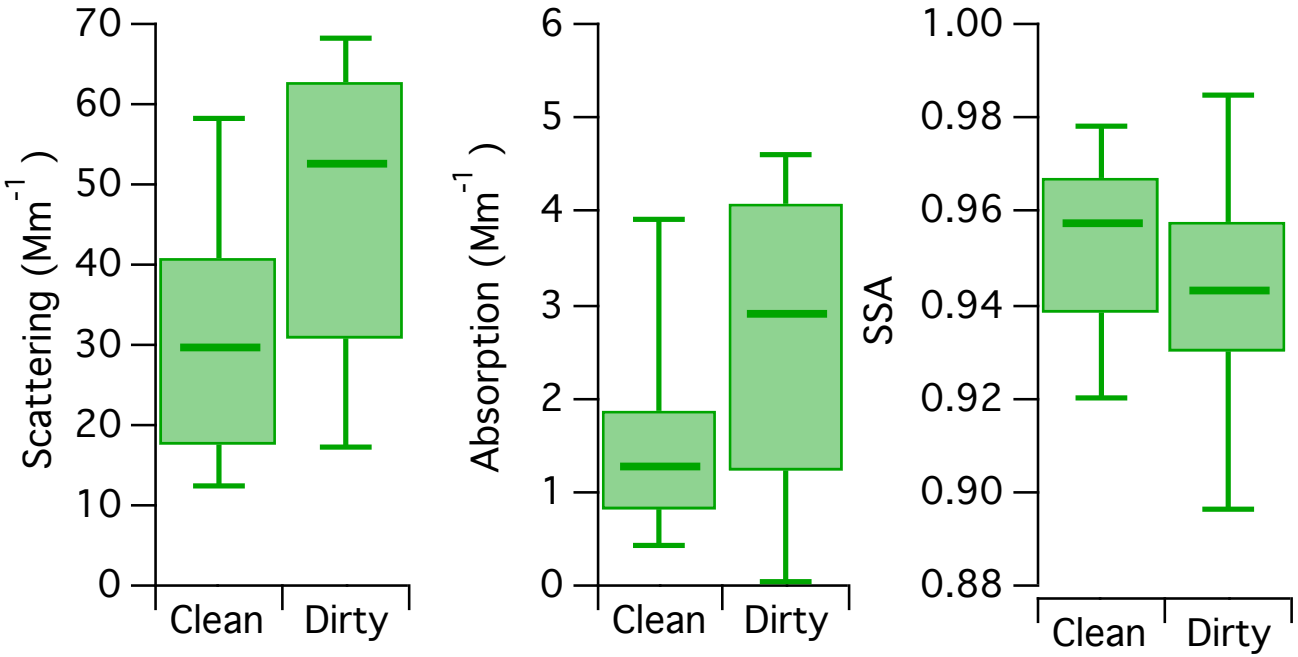
Cloud-Processing: Between Clouds

- Similar to sub-cloud results: increase in scattering and absorption associated with dirty air
- Decrease in SSA associated with dirty air
  - Larger range in SSA



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Motivation for CHAPS

- Below, within, and above clouds
  - How do the below- and above-cloud aerosol optical, chemical, and cloud nucleating properties differ?
- Inside and outside OKC plume
  - How are activated aerosols inside and outside of the urban plume different?
  - How are aerosols that have not been activiated different from those that have been?
- Distribution of extinction
  - How does the distribution of aerosol extinction vary in relation to the proximity to individual clouds and fields of clouds and why?

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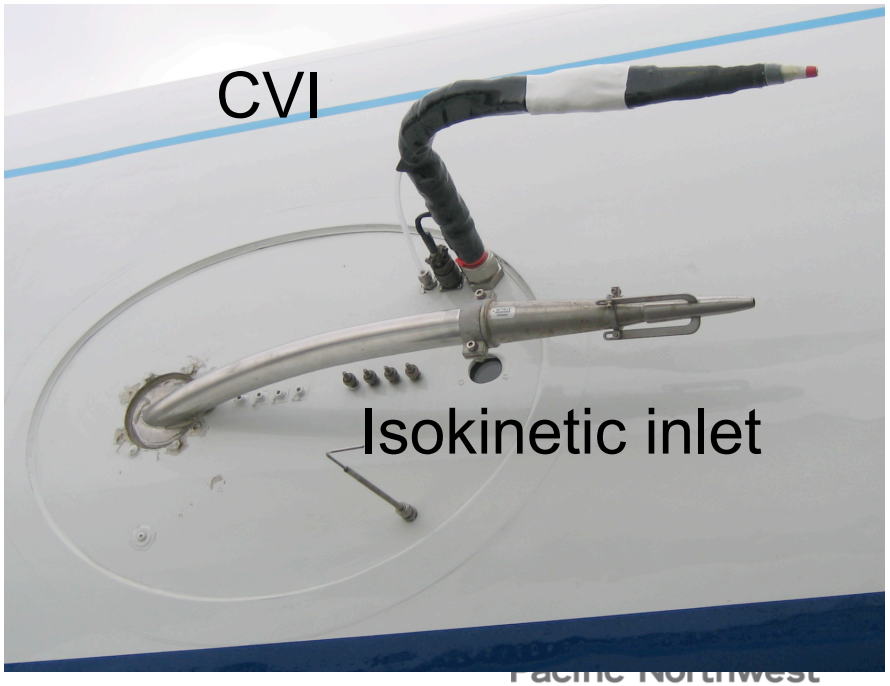
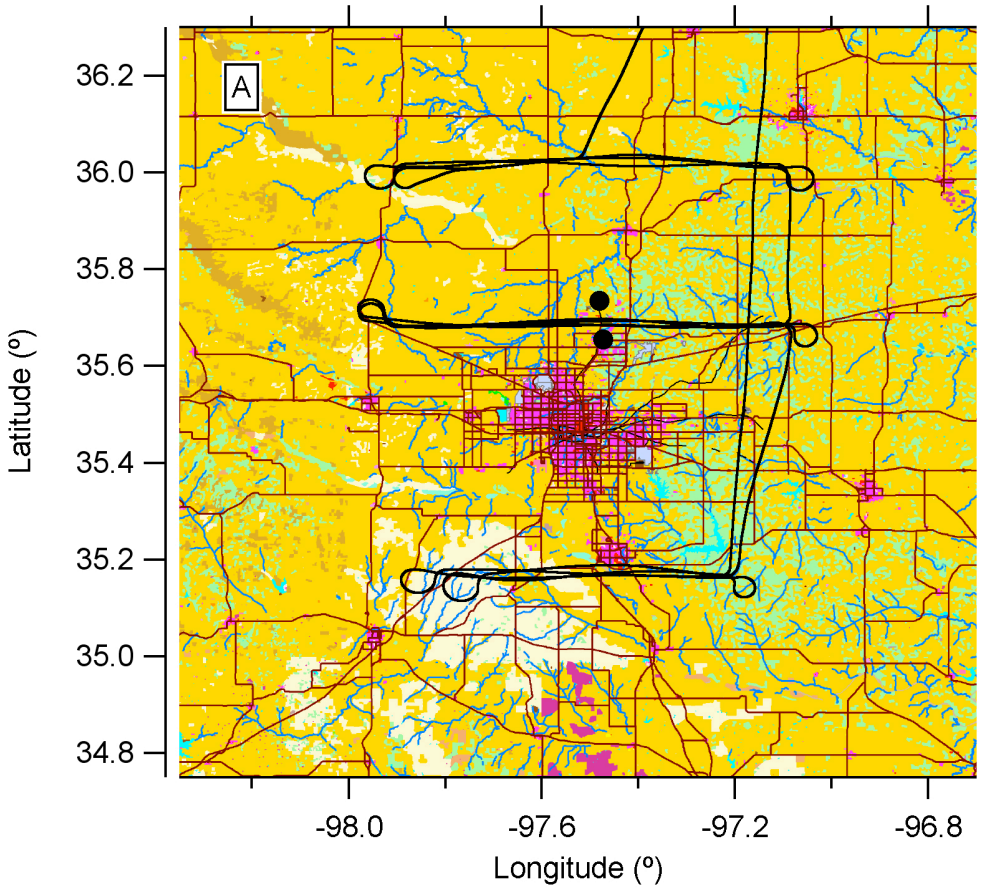
G-1 Instrumentation Used Here

- Two inlets
  - Cloud droplets sampled by Counter Flow Virtual Impactor (CVI)
  - Aerosols (D_p<2μm) sampled by Isokinetic inlet
- Nearly identical instrumentation on each inlet
- Detailed size and composition
  - PCASP & CAPS probes, SMPS, FIMS - particle and cloud droplet size distributions
  - Nephelometer, PSAP - particle optical properties
  - DMT CCN counter
  - AMS - Aerosol chemical composition
- Trace gases: CO



CHAPS Flight Patterns

- In and out of plume
- Below, within, and above the cloud layer



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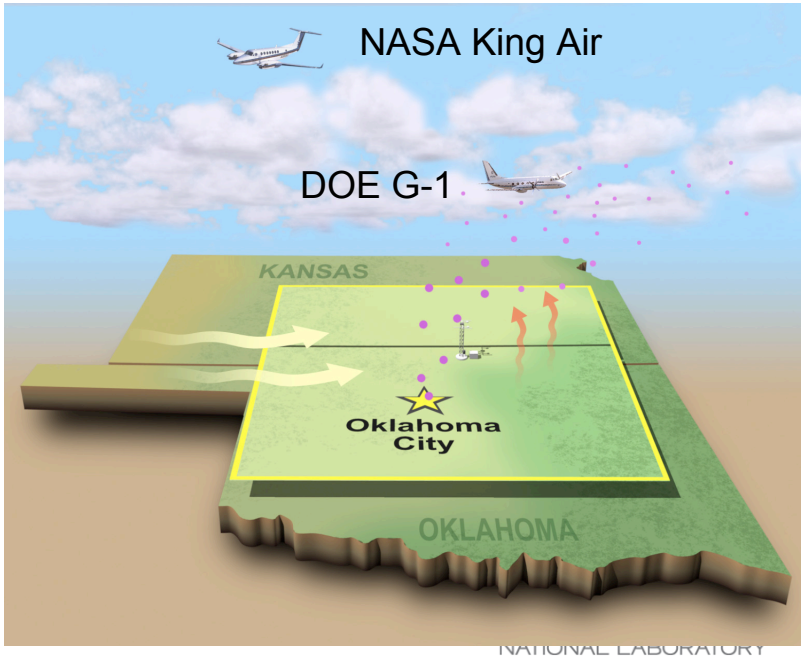
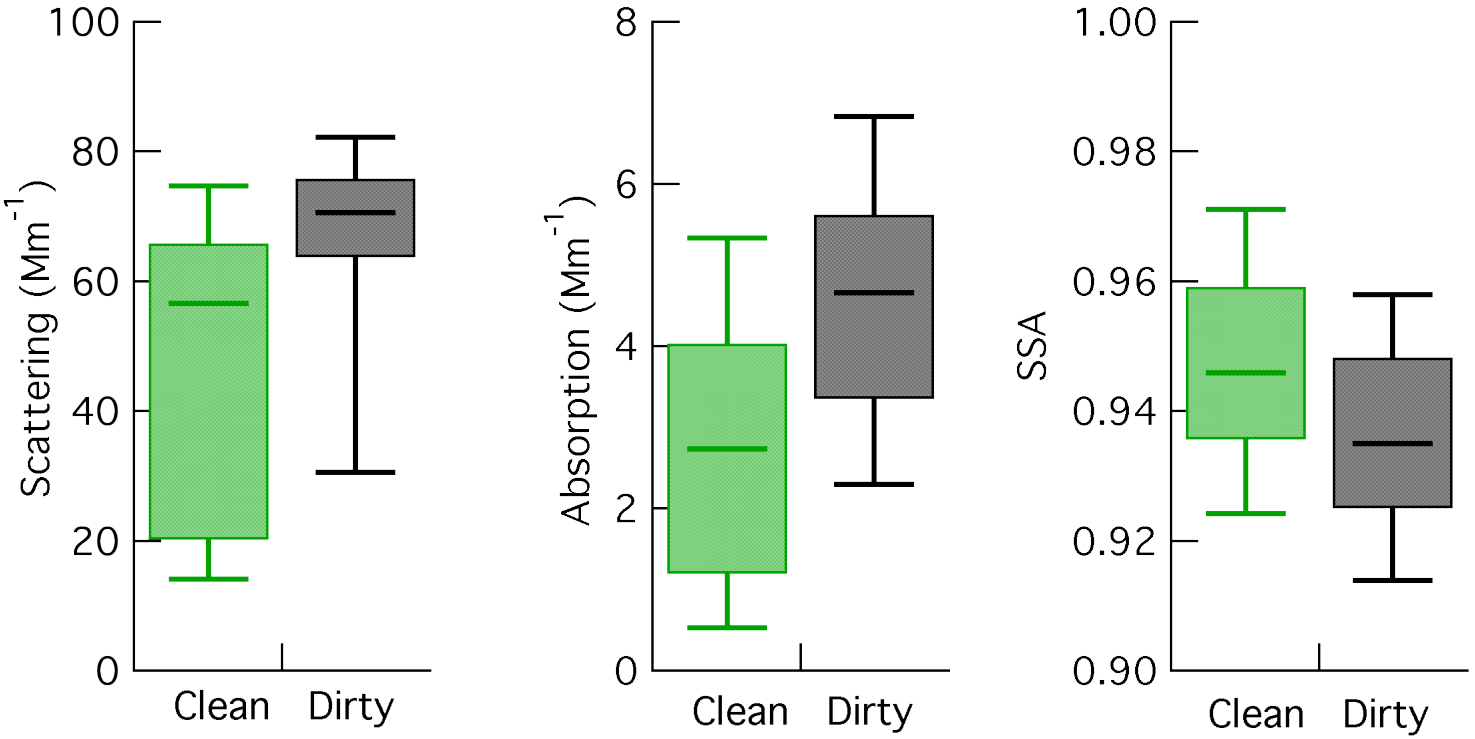
CHAPS Overview

- CHAPS
  - US DOE Atmospheric Science Program campaign to investigate cloud aerosol interactions
    - Aerosol chemical and optical properties
    - Cloud microphysics
  - Downwind of moderately sized city
  - Two aircraft and a surface site
- Cloud and Land Surface Interaction Campaign (CLASIC)
  - Concurrent with DOE Atmospheric Radiation Measurement program campaign linking clouds to surface properties
  - Nine aircraft and enhanced surface sites



Sub-Cloud Optical Properties

- Increase in scattering and absorption associated with OKC plume
- Decrease in Single Scattering Albedo (SSA)



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Chemical Composition

- In-cloud
  - In plume: increased nitrate, sulfate, decreased organics.
- Sub-cloud
  - In plume: increased organics, nitrate, decreased ammonium, sulfate